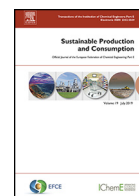




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Supporting a circular economy: Insights from Taiwan's plastic waste sector and lessons for developing countries

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ARTICLE INFO

Article history:

Received 13 July 2020

Revised 6 October 2020

Accepted 8 October 2020

Available online 10 October 2020

Editor: Prof. Konstantinos Tsagarakis

Keywords:

Waste recycling

Collective bricolage

Circular economy

Institutional governance

Taiwan

ABSTRACT

This study investigates how, in the process of industrialization, Taiwan successfully developed its plastic waste industry into an industrial-level circular economy by leveraging a network-based collective bricolage in conjunction with a framework of adaptive institutional governance. Three conclusions are made: industrialized manufacturing sectors are foundations upon which developing nations can accumulate endogenous social capabilities and can enable the emergence of network-based collective bricolages; for developing nations that are attempting to establish circular economies based on their endogenous small-to-medium enterprises, developing network-based collective bricolages in conjunction with adaptive institutional governance is an essential and effective strategy; and transitioning into green-related sectors can further drive economic development and lead to the creation of new ventures, businesses, and job opportunities while supporting the formation of a circular economy. The approach is especially relevant for developing countries starting their industrialization process and waste management initiatives with few resources.

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1. Introduction

Climate change has made resolving contradictions between needs for economic development and requirements for achieving environmental sustainability the most pressing issue of our time (Gowdy, 2020; Marques et al., 2018; Mathews, 2017; Hobson and Lynch, 2016). Traditional approaches to economic development are burdened by waste-producing and environmentally exploitative legacies. Meanwhile, environmental threats are growing due to the increasing demand for the resources that fuel economic development, especially in developing countries (De Koning and Cleaver, 2012). A new pathway needs to be found—one that does not require sacrificing environmental sustainability in exchange for increased socio-economic well-being—especially for nations that are still struggling to emerge from poverty. One sector in which exciting advances are being made in this direction is in waste management.

Before the United Nations Conference on the Human Environment in 1972, garbage was regarded solely as a liability. Sustainable waste management has been recognized as a core issue in developed countries (Barr, 2004), and even more so in developing countries that are burdened by waste due to lack of processing

capabilities or incentive mechanisms to reduce, reuse, and recycle their waste materials (Awasthi et al., 2016). In both types of nations, mismanagement of waste can lead to national health crises and seriously harm the environment. Ninety percent of the plastic items that people use in daily life, such as grocery bags, plastic wrap, disposable cutlery, straws, and coffee cup lids, are thrown out after a single use. Consequently, since the 2000s, plastic pollution in oceans has emerged as a major environmental threat (Obbard et al., 2014) prompting some countries to impose regulations and policies to ban the use of plastics (Khan et al., 2020).

Many challenges are involved in developing solutions to balance environmental sustainability and economic development (Wu et al., 2017). The dominant approach to addressing problems of waste has been attempts to alter socio-economic structures and cultural norms by targeting individual behavior through education (public service announcements), incentives, and disincentives (such as fines). These efforts are usually managed by non-governmental organizations (NGOs) or government agencies focused on educational programs and reliant on community participation.

Another approach that has been emerging is to recognize waste as a potential resource for economic growth. For example, the US startup Rubicon Global has successfully implemented a cloud-based waste recycling management system that provides on-demand trash pickup, develops smart waste and recycling solutions for business and governments, and maximizes the amount of waste being diverted from landfills. This business model led Rubi-

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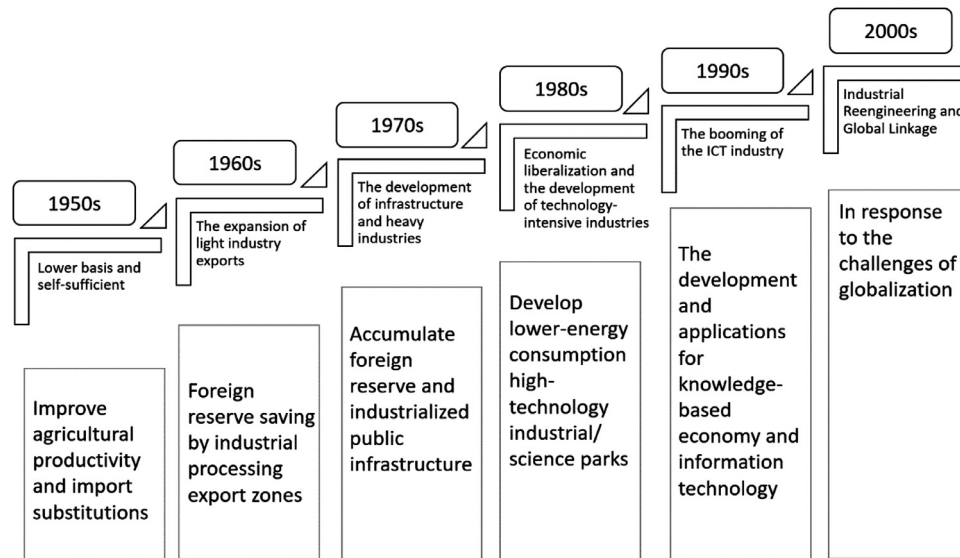


Fig. 1. Taiwan's economic development stages, 1950s–2000s.
Source: Source: Compiled by the authors.

con to emerge as the world's first “green” unicorn in 2018—that is, the first startup focused on environmentally sustainable solutions with an estimated market value of over \$1 billion (Fortune, 2018). Private-sector solution leaders like Rubicon are inspiring as most sustainable solutions in the world are not able to achieve financial independence. Our research suggests that flexible governance of public sectors that working in cooperation with industrial development as it progresses through different stages is a critical driver facilitating the success of green initiatives developing within the context of complex and interdependent endogenous socio-economic activities and cultural norms. This study explores how Taiwan has used this approach to integrate its plastic waste industry into an industrial-level circular economy.

Taiwan, once nicknamed “Garbage Island,” now boasts the world's second-highest effective recycling rate, following Germany (Eunomia, 2018). Thanks to a series of policies and regulation adoptions over the course of Taiwan's industrialization (as shown in Table 1), in 2018, Taiwanese citizens produced on average only 0.4 kg of waste per person per day. This was down from an average of 1.14 kg in 1998 and was substantially lower than the 2012 global average of 1.2 kg (Environmental Protection Administration (EPA); International Cooperation and Development Fund, 2018). Taiwan has reduced the amount of waste entering landfills to less than 2%, and the government has converted former landfill sites into parks and community centers. Additionally, 80% of Taiwan's industrial waste gets recycled (EPA, 2018). As of 2017, Taiwan had more than 4,000 registered recycling companies, up from fewer than 100 in 2007. The redesign, reproduction, and reuse of recovered plastic waste materials has not only closed the loop between production and consumption activities but has also made Taiwan a leading global partner among recycling industries and in green supply chains for textiles, information technology, and electrical and electronic components.

Taiwan's success in building a profitable and sustainable industry around reducing, recycling, and reusing plastic waste materials has been described as a model for the world (Eunomia, 2018). Taiwan's economy, 97% of which is comprised of small-to-medium-sized enterprises (SMEs), has undergone six industrial transformations between the 1950s and the 2000s (see Fig. 1 above). Taiwan transitioned out of being resource-poor and economically dependent into a resource bricolage between the 1960s and 1970s. In the 1980s and 1990s, it evolved into the entrepreneurial-driven

economic growth stage. Taiwan's economy entered its mature phase in the 2000s as national policy began to focus on reducing, reusing, and recycling resources.

Taking Taiwan's plastic waste industry as a case study, the goal of this research is to demonstrate how a network-based collective bricolage, developed in conjunction with an adaptive institutional governance approach, can address threats to environmental sustainability and support a high-performing industrial-level circular economy. Specifically, we investigate how a network-based collective bricolage can influence the conversion of resource value in businesses and industries to facilitate the establishment of a new socio-economic paradigm. This study reveals that, on a practical level, industrialization associated with adaptive institutional governance is essential, especially for developing or late-comer economies that are striving to catalyze and facilitate industrial development. At the same time, the study also carries implications for developed nations seeking to address the tensions between continued economic growth and environmental protection.

2. Literature Review

In this section, we discuss the related literature of entrepreneurial bricolage, network-based collective bricolage, and their relationship with institutional governance and socio-economic institutions in Taiwan.

2.1. Entrepreneurial bricolage: individual versus collective

Bricolage is the process of improvisation in a human endeavor. It has been described as the re-mixture, re-construction, and re-use of under-utilized resources to produce new meaning and value. Scholars have suggested that bricolages can have both beneficial and harmful effects (Baker and Nelson, 2005; Senyard et al., 2009) yet occasionally produce highly innovative outcomes (Strauss, 1962).

In entrepreneurship, bricolage theory focuses on explaining how entrepreneurship emerges in economically depressed or resource-poor areas by creating something new from under-utilized resources and transforming them into productive resources (Baker and Nelson, 2005). In this context, lack of resources and low-quality resources drive the use of ‘the savage mind’ to innovate (Lévi-Strauss, 1962) and produce entrepreneurial bricolages

Table 1
Taiwan's waste- and recycling-related laws and policies, 1974–2017.

Year	Acts	Adaptions	Socio-economic norms
1974–1983	Laws are not effectively implemented; garbage dumped openly	Promotion of Buddhist values about cherishing what people have	Society begins to develop consciousness around waste
1984	Municipal Solid Waste (MSW) Disposal Plan establishes first sanitation landfill	Change from open burning to landfill disposal reduces air pollution from burnt waste	Businesses specializing in the resale of used items become more popular
1987	Introduction of extended producer responsibility policy (EPR) directs producers to reduce waste	Plans begin for the subsequent launch of the Resource Recycling Funds	Number of collection stations increases
1990	MSW policy adjusted; shift from landfill disposal to incineration with better garbage sorting	Transitional period during which garbage and waste increases and policy-makers proceed through learning by doing/trial and error	People take up the habit of sorting and utilizing MSW services
1991	Garbage Disposal Act created to ensure enforcement of waste incineration and landfill policies	Taiwan experiences its economic golden years, i.e. the booming of ICT manufacturing led to a rise in consumption (see Lee et al., 2000)	The amount of waste increases dramatically
1998	Eight Resource Recycling Funds are established	Producers pay recycling fees to eight recycling funds that subsidize, promote, monitor, and reward waste management (see, for example, Bor et al., 2004)	The recycling sector begins to formulate
2000	Electric industrial waste reporting and monitoring system implemented Eleven incinerators are built around Taiwan	Extended user responsibility policy is implemented, directing consumers to reduce waste.	The ratio of recyclable waste in relation to general waste is only 1.9% in 1999. Industrial waste reporting and management information system increases the efficiency of industrial waste recycling, supporting the growth of recycling ventures and businesses
	Announcement of emissions standards for small- and medium-sized incinerators	Shift away from public service education and toward a focus on industrial regulations aimed at influencing industrial behavior	
	Waste Electrical and Electronic Equipment (WEEE) Disposal and Recycling Policy passed Enactment of the policy requiring the use of official garbage bags in the capital city of Taipei Establishment of the Industrial Waste Control Center		
2001	Campaign to promote the recycling of kitchen waste	Moderate regulations implemented; recycling-related awareness and compliance among households and schools increases	Recycling gains social legitimacy and becomes regarded as merit-gaining behavior.
2002	Passage of a source reduction initiative to restrict plastic shopping bags and disposable tableware	Moderate regulations implemented, reinforcing recycling-related awareness	Compliance among households and schools increases; recycling becomes widely-recognized as a merit of society as a whole
2003	Evaluation of resource regeneration and reuse and of zero waste practices	Additional related public institutes were established	Additional NGOs and social enterprises enter the industry
2005	Mandatory garbage sorting; policies enacted to keep trash off the ground by facilitating better trash collection and sorting	Authorized public sector is restructured to respond to the increase in responsibilities; systems for supervising and monitoring local agencies are established; an environmental protection science park is created to process recycled waste	Consumers start to share the cost of the recycling process in the form of higher prices for green products/services
2007	Creation of resource recycling promotion plan for general waste	More existing private companies enter the recycling industry	Business profits increase in the recycling sector
2010	Biomass-energy Center is constructed	Pursuit of upgrades in technology and green industries	Environmental conscientiousness becomes widespread as a societal norm
2016	Landfill site is reactivated (to support the development of biomass energy) The EPA raises the goal for resource recycling	Resource recycling ratio reaches 52.5% in 2017 (up from 1.9% in 1999)	Green lifestyle (products and services) welcomed but regarded as expensive
2017	Achieving a circular economy designated as a matter of national strategy	Recognition that more detailed regulations and laws need to be legislated	As producers' perception of social responsibility increases, industries focus effort on providing affordable green products and services

Source: Various public reports compiled by the authors.

([Baker and Nelson, 2005](#); [Garud and Karnøe, 2003](#); [Senyard et al., 2014](#)). Scholars have referred to innovation under these conditions as 'adversary innovation' ([Radjou and Prabhu, 2015](#); [Zeschky et al., 2011](#)). Bricolage, in this context, is the application of capabilities to break through a *de facto* environmental boundary, institutional boundary, or mindset boundary ([Powell and Baker, 2014](#)). Under this approach, entrepreneurial insight is essential for picking, sensing, and acquiring usable resources and determining feasible actions to recombine these materials to fit resources and create novel processing methods.

The literature exploring entrepreneurial bricolage has addressed various ways to recombine, re-activate, and reconstruct negative resources into positive assets (see, for example, [Boxenbaum and Rouleau \(2011\)](#) and [Fisher \(2012\)](#)). However, the 'hidden' process of converting negative resources into productive resources has not been explored. Negative resources, such as garbage, used to be considered liabilities to private companies and the greater society and economy. However, well-managed entrepreneurial bricolage can transform these liabilities or constraints into opportunities, redefining waste materials as valuable resources.

Ciborra (1996) purports that while a bricolage-based approach may help firms to adapt, it also constrains the scale of a firm's operations. When entrepreneurs engage in intensive bricolage, they may find it difficult to move beyond an initial 'good enough' solution to a 'best-fit' solution and thus may fail to expand their consumer base. In response, Baker and Nelson (2005) suggest that bricolage may therefore be harmful if applied only to the top administrative levels of an individual entity, but that it could be beneficial if implemented broadly among many interested parties (i.e. a collective bricolage). In a collective bricolage, cost-effective network-based relationships can overcome the negative effect of individual bricolage in confronting dynamic variations and uncertainties, especially when it is applied in a collaborative network (Duymedjian and Ruling, 2010). For an industrial structure composed of SMEs, such as Taiwan, networking activities are critical to affect the market and promote collaboration along the value chain (Chou et al., 2019). For example, Garud and Karnoe (2003) adopted a network-based collective bricolage approach for the development of Denmark's wind turbine industry. They showed how a network of stakeholders, comprised of producers, users, regulators, and evaluators jointly contributed to the creation of a profitable technological path for the wind turbine industry as a whole. The network-based collective bricolage thus not only overcame the disadvantage of individual bricolage but also secured the external advantage created and diffused from the collaborative network.

2.2. Institutional governance

Institutional governance is an evolving process aimed at creating a balance between state and civil society while transferring responsibilities of the government to public institutions. This involves various processes and regulatory provisions that support institutions as they achieve their planned targets and outcomes. Institutional governance encompasses how public sectors shape the functions of departments and entities connected to them, the incentives and regulations in place for individual members of the institution, financial design and allocation, and mechanisms for connecting to outside actors (Griffiths and Zammuto, 2005). Beyond its connotations for innovation studies, the process of institutional governance considers the co-evolution of technology, diverse actors, social norms, and historical and cultural characteristics (Geels, 2004). Accordingly, institutional governance models vary and evolve to become adaptive to fit local situations at different points of time (Glaeser et al., 2004).

Scholars in the tradition of Schumpeter (1934) have widely demonstrated that industrialization is a diffusible and reproducible developmental model that has given rise to unprecedented levels of prosperity and lifted millions of people around the world out of poverty (see, e.g. Freeman, 2008; Mathews, 2017). Institutional governance was a critical driving force in the success of Asian industrialization, guiding the dynamic interplay between actors and structure as industrialization diffused from the West throughout the East, to Japan, the Four Asian Tigers (Korea, Taiwan, Singapore, and Hong Kong), and China (Hu and Mathews, 2005; Geels, 2004).¹ Many scholars have argued that institutions both constrain and enable freedom; however, such constraints can also fuel entrepreneurship and open up possibilities for novel choices and actions (Hodgson, 2006). In such a process, the network-based collective bricolage emerges from critical engagement among stakeholders within a setting of social and cul-

tural complexity, historical context, and social norms (De Koning and Cleaver, 2012).

The present study indicates that, in the case of Taiwan's waste recycling sector, adaptive institutional governance led to the aforementioned path of possibility and innovation, resulting in the successful establishment of an industrial-level circular economy. Through the concerted efforts of various levels of government to initiate and organize events and networking activities, and to facilitate dialogue among stakeholders, the institutional governance approach has led to the emergence of a lively ecosystem of institutional entrepreneurship in Taiwan.² We explore how Taiwan industrialized its plastic waste sector by employing a network-based collective bricolage which, along with adaptive institutional governance, was able to turn liabilities into valuable assets. We also highlight this case as further evidence that institutional-led efforts to raise awareness of resource interdependency can lead to the creative alteration, reinterpretation, and reconstruction of negative resources to create value (also see Rindova et al., 2011; Zott and Huy, 2007).

2.3. Resource recycling versus socio-economic institutions in Taiwan

Taiwan lacks certain natural resources and as a result, 90% of the island's energy is imported. As in many developing economies, Taiwan's recycling system began with manual pick-up, collection, and resale activities. In the early 1970s, there was a complete lack of public consciousness about responsible waste disposal. Garbage was dumped openly everywhere. The process of institutional governance establishes systems that structure social interactions, and it was to this end that Taiwan's Waste Disposal Act was enacted in 1974 when Taiwan's economic development, alongside that of the other Asian Tigers, began to accelerate. The first step taken by the government was to launch a public service campaign aimed to educate people about waste and, through the promotion of Buddhist dogma already widely accepted in Taiwanese society, encourage people to cherish what they have at hand. The second step was to create many small collection stations. This was followed by the institution of programs that would provide commercial incentives to retailers, wholesalers, and re-sellers to reduce waste and recycle. The Waste Disposal Act has since gone through 14 legal revisions, the latest in 2017, to provide guidance throughout the institutionalization and industrialization of Taiwan's waste recycling sector and to align this process with Taiwan's overall socio-economic development, as illustrated in Table 1. This process has seen leaps in the sophistication of technology, an increase in the diversity of actors involved, the normalization of environmentalism in society, and related advances in conservation culture. Policy revision has been particularly rigorous since 2000 in response to resource-intensive economic growth derived from booming high-tech industrial development in Taiwan (see Fig. 1).

3. Methods

Numerous factors contribute to the challenge of successfully transitioning from an industrial economy to a circular economy, and these variables are difficult to measure through statistical or other quantitative methods. This study adopts a qualitative research approach in acknowledgement that the literature lacks a

¹ A flexible and adaptive approach to institutional policy and regulation that supports industrial development at different stages is one of the critical drivers to avoid the 'middle-income trap' as experienced by many Latin American and Southeastern Asian countries (Asia Development Bank, see <https://www.adb.org/sites/default/files/publication/28608/asia2050-executive-summary.pdf>).

² Institutional entrepreneurship is a concept that reintroduces agency, interests, and power into institutional analyses of organizations. Maguire et al. (2004, p. 657) refer to institutional entrepreneurship as "activities of actors who have an interest in particular institutional arrangements and who leverage resources to create new institutions or to transform existing ones." These actors, namely institutional entrepreneurs, create a whole new system of meaning that ties the functioning of disparate sets of institutions together (Garud et al. 2002).

structured or effective approach for analyzing an economic shift to a circular model, especially in the Asian context. Specifically, the present study is based on action research, a method that has been applied across various social science disciplines. In contrast with other social science research methods that consider specific social actors as objects for study, action research emphasizes taking practical problem-solving actions while also building a body of knowledge. Researchers use this method not only to gain an understanding of a specific socio-institutional arrangement but also to contribute to solutions for practical problems through collaboration with relevant community members who experience the effects of the problem under research (Bradbury-Huang, 2010; Brydon-Miller et al., 2003; Coughlan and Coughlan, 2002).

Participatory action research is collective reasoning and evidence-based learning, therefore, this type of involvement enabled the authors to participate in different interactions and conduct an in-depth exploration of how actors within the system interact and engage in the collective bricolage to achieve necessary action-based solutions. This study makes use of both second-hand data sets and first-hand data collection (through action research). We first surveyed and reviewed the relevant secondary-source documents and reports from public institutes and interviewed companies to understand the context of the transitional processes and to collect comprehensive data. To collect first-hand data, two methods were used to transcend the limitations of each method when used individually, namely participant observation and in-depth interviews. This allowed us to mutually authenticate data generation and produce more effective solutions when problem-solving (MacDonald, 2012).

- 1 Participant observation: This method provided researchers with privileged access to research the subjects of Taiwan's circular economy, allowing them to record both subjective and objective behavior. Although the researcher may become biased or may have a stake in the topic during the participatory action research, that bias may be offset by the problem being solved as facts are identified, action is taken, and outcomes formulate in a way that ultimately leads to further inquiry and action.

The authors of the present study are currently involved in projects related to Taiwan's circular economy. The first and second authors have contributed to the strategy development of one of the national plans, and the third author is also a key supplier of recovered plastic waste materials. As participants in the process being observed, while immersed in the situation along with others, the authors made efforts to assure that all participant viewpoints were recognized. Differing points of view were encouraged, and all were given ample opportunity to communicate. As a result, the authors were able to obtain a broader view of what was occurring than would have been possible from a strictly external perspective and had the opportunity to collect first-hand data by recording details of what was communicated and what was implicit in the situation.

For example, the downstream applications of waste plastics are diverse; different sectors have their self-interests for waste categories, standards, and subsidy needs.³ Conflicts between stakeholders frequently emerge. Third-party participants, such as the authors of this study and others from academia and research institutes, are regularly asked to act as moderators and consultants.

³ One example of differing self-interests concerns the setting of standards for subsidy rates. We found that NGOs prefer a constant subsidy rate providing stable support for its operation. Meanwhile, collectors request a lower subsidy rate to prevent the development of a market for the import of waste. In contrast, downstream application companies demand a higher subsidy rate to secure the source and quality of their materials. After intensive debates and discussions, a consensus was reached and a system of fluctuating subsidy rates was adopted so that the actions taken by the Recycle Management Fund can be adapted along with fluctuating supply and demand.

While at times third-party participants may be used by contesting stakeholders to gain legitimacy, such institutional roles also help to justify or propose a neutral action plan, aiming to prioritize the problems and maximize the socio-economic benefits for further movement.

- 1 Interviews: By stimulating lively conversations, in-depth interviews conducted using unstructured, open-ended questions can reveal profound information that may not become evident from quantitative methods. (See the appendix for the list of interview questions used.) In this method, a researcher guides the direction of the interview while also offering the interviewee considerable freedom to express their ideas (Babbie, 2001).

Between 2017 and 2019, the authors conducted a total of 32 in-depth interviews with 16 different actors within the industrial-level circular economy (14 actors are private companies and 2 are public institutes, see Table 2). Because Taiwan's plastic waste recycling industry is divided into five sectors (as shown in Fig. 5), we adopt modal instance sampling to select the typical members as representatives from each of the five sectors (i.e. the top 2-3 players with the highest annual sales in each sector). These interviewees of the top players were either referred to the authors by specialists in public institutes or recommended by the active participants in various meetings and workshops that had been organized by various formal and informal institutes. Their knowledge of the circular economy comes from their engagements with it as members of NGOs, various types of companies along the industrial value chain, government agencies, public authorities, and civil groups. These organizations were selected because their performance in the industrial value chain has been recognized by public authorities and consultants. Additionally, their founders and/or top managers were known to be active and enthusiastic about sharing their thoughts which greatly help to reduce variations of causality in our inductive reasoning. Bearing in mind that generalization process within participatory action research is not automatic, the findings reported in the results section are generalized when similar replications indicated by at least five interviewees and discussed in participatory workshops or activities. According to Yin (2009, p. 36) "once such replication has been made, the results might be accepted for a much larger number of similar individuals, even though further replications have not been performed".

Each official interview session lasted 30 to 180 minutes; some were interviewed several times on different occasions to cross-check for consistency and obtain further verification. If the data gathered in the initial interview was unclear, the interviewees were re-contacted by phone or other means to obtain clarification.

4. Results and Discussion

Through analyses of both first-hand data and second-hand data sets, we interpret our findings as follows.

4.1. Establishing an industrial-level circular economy: Institutional governance

The European Commission (2014) proposed that seven components are required to achieve transformation into a circular economy: (1) skills and knowledge, including entrepreneurship, capacity-building, and multi-disciplinarity; (2) organizational innovation, including integrated solutions and systems, logistics, business models, and policy-supporting tools; (3) social innovation, including new production and consumption models, citizens' involvement, product service models, and design services; (4) technological innovation, including design of materials and processes, product design, and resource management (waste, water, energy, and raw materials); (5) financial instruments; (6)

Table 2
List of interviewees, 2017–2019.

Year	Date	Company code	Job position	Length of Interview
2017				
1	11 October	Company 1	Chairman	2 hrs.
2	28 October	Company 1	Chairman	3 hrs.
3	24 November	Company 2	Chairman	3 hrs.
4	24 November	Company 3	Chairman	3 hrs.
5	5 December	Company 4	Chairman	2 hrs.
2018				
6	30 March	Company 5	Owner	1.5 hrs.
7	15 June	Company 2	Chairman	2.5 hrs.
8	14 July	Company 5	Owner	1.5 hrs.
9	2 August	Company 6	Sales Manager	1.5 hrs.
10	11 August	Company 7	Chairman	1 hr.
11	14 August	Company 2	General Manager	1 hr.
12	22 August	Company 7	General Manager	0.5 hr.
13	31 August	Company 8	Manager	1.5 hrs.
14	2 September	Company 3	Chairman	2 hrs.
15	4 September	Company 2	Chairman	3 hrs.
16	13 September	Company 8	General Manager	0.5 hrs.
17	19 September	Company 2	Chairman	2 hrs.
18	16 October	Company 9	Owner	1.5 hrs.
19	27 October	Company 2	General Manager	1.5 hrs.
20	27 October	Company 5	Owner	1.5 hrs.
21	12 November	Company 10	Chairman	3 hrs.
22	13 November	Public Institute 1	Deputy Director	1 hr.
23	15 November	Public Institute 2	Deputy Director	1.5 hrs.
24	23 November	Company 11	Owner	2 hrs.
2019				
25	5 January	Company 5	Owner	1.5 hrs.
26	10 January	Company 10	Chairman	40 min.
27	19 January	Company 11	Owner	2 hrs.
28	13 April	Company 12	Chairman	1 hr.
29	19 April	Company 3	Vice President	1.5 hrs.
30	20 April	Company 13	Manager	2 hrs.
31	4 May	Company 11	Owner	2 hrs.
32	4 June	Company 5	Owner	1.5 hrs.
33	30 July	Company 2	General Manager	1.5 hrs.
32	2 October	Company 14	Owner	1.5 hrs.

awareness, dissemination, and internationalization; and (7) multi-stakeholder involvement. Government and corporate actors are critical to realizing many of these components and transformations through the redesigning of products and processes (Murray et al., 2017). Through the processes of institutional governance, in Taiwan, these seven components have been applied and adapted by various stakeholders, including citizens, waste collectors, producers, consumers, and public agents along the industrial value chain. This framework has exhibited a substantial effect through Taiwan's network-based collaborative bricolage as the industrial structure of the island is 97% composed of SMEs. To fulfill the different needs of numerous SMEs, institutional governance has adapted along with evolving policy goals and socio-economic change while consistently aiming at establishing an industrial-level circular economy by integrating and coordinating the actors of the seven above-mentioned components (see Table 1).

Under the leadership of the institutional governance process, Taiwan's recycling industry has become an interconnected and evolving entity; relevant actors include producers, importers, vendors, users, agents, firms, public authorities, and civil groups (see Fig. 2). During the intensive debates and discussions at events held by many formal or informal institutes, different actors indicate various interests whereas the third-party participants (often the researchers from public sectors such as the authors) act as moderators and consultants. Each actor responds to and modifies the process according to their needs within the context of a dynamic environment. For example, in Fig. 2, the arrow on the left shows that the rate of payments made by manufacturers to the recycling management funds for waste processing fluctuates according to re-

ported sales as well as import quantity. To compensate, subsidies are determined according to the capacity of recycling and recovery technologies, the goals set by public authorities, and the demand from recovery manufacturers. Such institutional entrepreneurship is demonstrated by Taiwan's professional technocrats in the adaptive process of institutional governance, as seen in Fig. 2, in relation to all the stakeholders.

"...it was good to have Dr. X (from public institute 1) in that workshop so he could offer a fair proposal for everyone. Otherwise, I don't think I would ever talk to Mr. C.Y again....he is too greedy and doesn't care about his partners at all. This is not right. We should work together to make it happen, even though we need to sacrifice a little (profit)..." (Owner at Company 11)

The purpose of the institutional design by these technocrats is to ensure the sustainability of the industry. Therefore, when the demand for recycled product manufactures increases (for example, an increase in orders from international buyers), the associated subsidy can be modified, reduced, or withdrawn, thereby encouraging public authorities and committees to devote more resources to refining administrative practices, auditing, and forming regulations and policies to further develop the industry.

Fig. 3 illustrates the closed-loop recycling of resources such as plastic waste in Taiwan's industrial-level circular economy. In this process, materials move with zero waste through the stages of recycling, modification, green design, green manufacturing, consumption, and usage. They are then dismantled into residuals whereupon the cycle restarts at recycling. Taiwan's circular economy is a multi-industrial circular circle rather than a single industrial loop. The diverse downstream applications absorb various

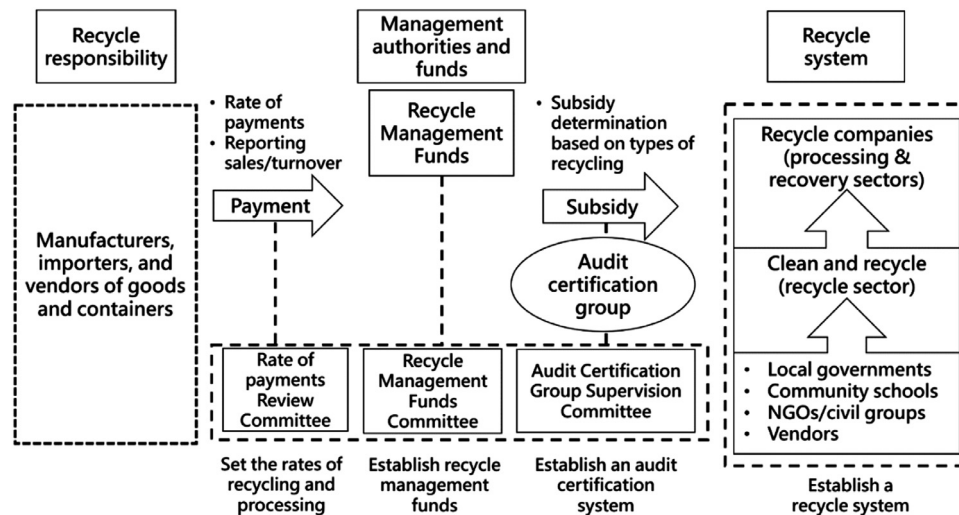


Fig. 2. Recycling framework under interconnected institutional governance in Taiwan.

Source: Source: Ministry of Economic Affairs, Taiwan

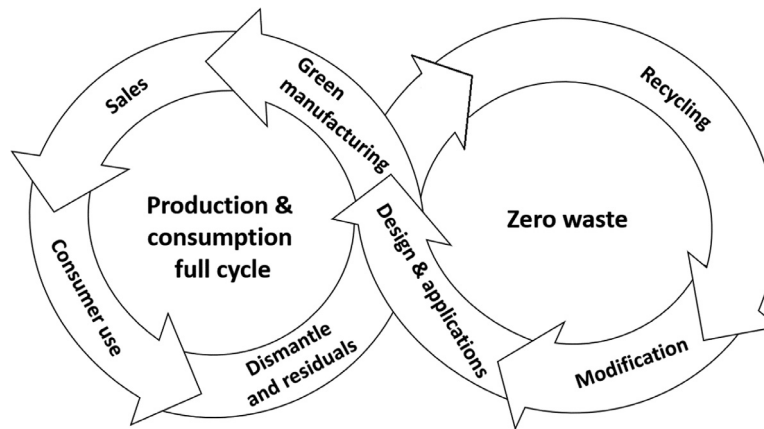


Fig. 3. Resource recycling in a multi-industrial -level circular economy.

Source: Source: Adapted from the concept of a circular economy, for example see:

<https://ec.europa.eu/jrc/en/news/research-helps-europe-advance-towards-circular-economy> (2017).

sources of dismantles and residuals and convert them into multi-industrial circular flows.

"We are not worried about the market... Taiwan has too much demand...In fact, how to secure the supply of raw materials is our biggest concern, so we are discussing a merger or joint venture with the second-largest supplier. The most important thing is we find a win-win operational model" (Chairman of Company 2).

4.2. Network-based bricolage v.s social capability⁴

Fig. 4 illustrates the plastic material mechanical recycling process as an example. The process includes collection, sorting, granulating, washing, drying, extruding, water cooling, and cutting into pellets. The collection and sorting activities are labor-intensive and require critical attention to ensure the quality of recovered materials for the later phases of processing, which will determine the potential applications for and value of the product on the mar-

ket. Companies with international brands evaluate recovered materials according to quality as they select global suppliers for green materials. Taiwan has numerous SMEs, such as original equipment manufacturers (OEMs)/original design manufacturers (ODMs), that specialize in such production activities and possess related know-hows, namely social capability, to quickly insert themselves into different industrial value chains.

"This business does not have high-tech requirements... not like the semiconductor industry (another of Taiwan's specialized industries)...but the know-how and especially the relationships with the waste collection stations are very difficult to break into.....their language (business culture) is different from ours...but I know how to deal with them..... (Chairman of Company 10).

The labor-intensive and capital-intensive activities along the value chain of Taiwan's recycling industry involve distinct areas of social capability and know-how. Consequently, the industry is fragmented, and the network-based bricolage has emerged in three sectors, namely (1) resource recycling stations (including labor-intensive collection and sorting activities), (2) granulation and washing, and (3) recovery (capital-intensive extrusion and specialized cutting know-how). Many companies are not new entrants to the general market; most of these firms were already specialized in other sectors when their leaders, with their accumulated social capability, recognized the synergistic opportunities available in

⁴ Social capability includes both intangible and tangible capabilities (Abramovitz, 1986). The former implies a platform which is composed of intangible inputs (such as social norms, structures, cultural values, the level of knowledge base, and absorptive capacity in the economy as a whole) and the latter is a set of tangible resources (such as R&D expenditure and manpower inputs) utilized to reinforce and support the technological development.

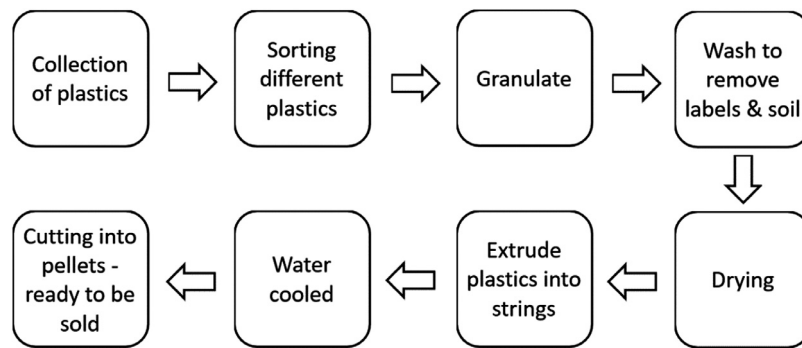


Fig. 4. Mechanical recycling and modification process for plastic materials
Source: Source: Authors' investigations and observations.

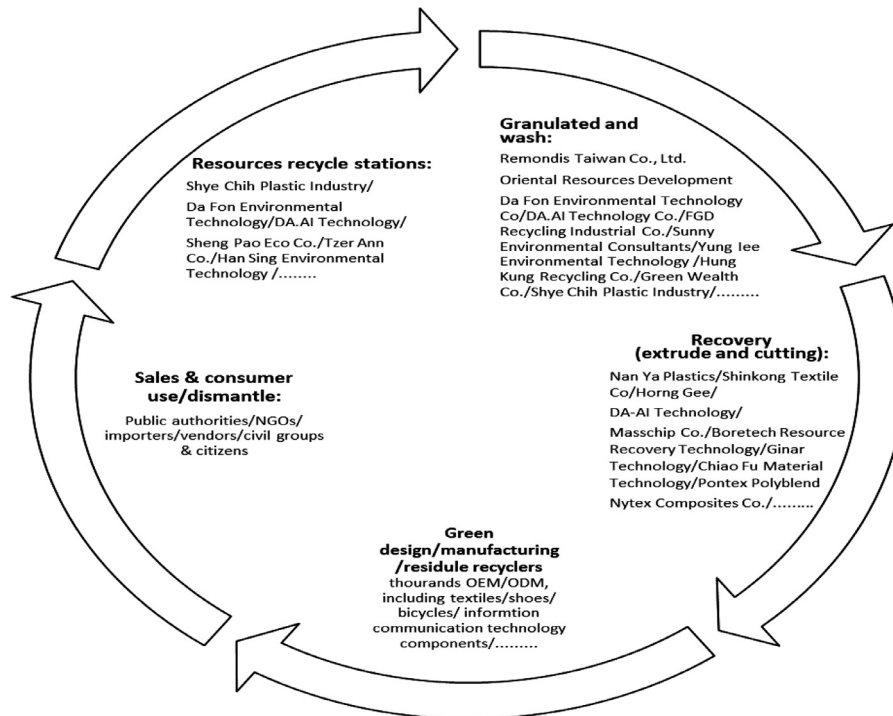


Fig. 5. Intensive network-based value chain of Taiwan's plastic waste recycling industry, major firms only.
Note: Thousands of firms are involved in these processes; here, we only indicate the major firms for each stage of the value chain.
Source: Source: Various reports compiled by the authors.

the recycling industry (see Fig. 5). For example, the Chairman of Company 10, originally a successful player in the foam industry, found the company's specialized production processes to be perfectly suited to extruding and cutting plastic waste materials. Additionally, Taiwan's two leading textile companies, Far East and Shin Kong, used institutional support to jointly establish a waste recovery company, Taiwan Recycling Corporation (TRC) (Tseng, 2019). The companies' aim in founding TRC was to secure and process waste polyethylene terephthalate (PET) bottles as a green material for textile products, in response to international clients' requests.

4.3. Transitioning into green manufacturing

Recycled plastic waste materials have numerous downstream applications for daily-use goods. Taiwan's first transition from an agricultural economy to a labor-intensive industrial economy (e.g. based on the manufacture of textiles, shoes, and bicycles), and second transition to a high-tech industrial economy (e.g. based on the manufacture of information and communications technology

(ICT) and biotechnologies), has involved the development of foundational designs and applications for recycled plastic waste materials. For example, bio-based plastics such as polylactic acids (PLAs) and polyhydroxyalkanoates (PHAs) are environmentally friendly, degradable, compostable, and have many viable applications on the market, such as use in plastic components for ICT products, filament for 3D-printed products, and mulch film for green agriculture (Based on the information provided by Company 10).

Most of Taiwan's companies are OEMs/ODMs that primarily export their products. Green manufacturing in Taiwan is thus driven not only by increasingly strict domestic regulations and related policies but also by the standards demanded from international customers, especially companies that own international brands and prioritize brand reputation and image on the market. Using the materials of recycled PET bottles in Taiwan's textile industry is one example of green manufacturing. In Taiwan, recycled bottles are recoverable, but Taiwan's Food Hygiene Policy stipulates that recycled containers may not be used as food containers. Therefore, 60% of Taiwan's recycled PET bottles are used in textile fibers (re-

covered PET fabric), facilitating the transformation of the traditionally high-polluting textile industry. Many Taiwanese OEMs/ODMs, such as the textile companies Far East and Shin Kong, have received requests from ADIDAS to produce shoes and sportswear fabricated from 100% recycled fiber by 2020. Additionally, Shin Kong successfully entered Nike's supply chain based on demand for its recovered "Sigma" fibers and won orders from 13 countries for customized Fédération Internationale de Football Association (FIFA) sportswear in 2018.

"As a public institute, we received many different requests and inquiries for loosening/tightening enforcement for the regulations and policies...what we can do is, based on the industrial policy, find ways to maximize the effect and offer the best-fit solution for the economy as a whole...We often tell companies to think about 'how to make money while also doing something good (for the earth)' ...this is to increase their responsibility while guide them to transits into green manufacturing..." (Deputy director of public institute 1).

4.4. Institutional entrepreneurship continues

In addition to the growing demand for green products from clients with international brands, producers and consumers in Taiwan have been influenced by domestic regulations and policies that emphasize the responsibilities and incentives of relevant parties (Table 1). In the latest such policy, the administration under Tsai Ing-Wen officially established the goal of creating a circular economy as an area of national strategy. Specifically, the 'Reduce, Reuse, Recycle Campaign' (from 2018 to 2020) emphasized zero waste and closed-loop processes that connect design (through cradle-to-cradle approaches), production (through extended producer responsibility (EPR)), sales (through value-sharing schemes, such as rentals), and use (through right to use rather than right to own) activities. In consideration of the dependence of Taiwan's economic development on industrial transition and transformation, the campaign prioritizes industrial zones and science parks as initial targets. This institutional policy reinforces the role of producers in industrial zones and science parks (which are directly administered by central governments) in expanding and adapting the success of the plastic waste sector circular economy into other sectors. To remain in public-administrated science parks, producers are required to advance their participation in the circular economy and assure their business models comply with international standards in preparation for Taiwan's forthcoming 7th industrial transformation. Although achieving this will be more complicated than it was in the plastic waste sector, policy-makers (technocrats) are aware that green initiatives taken by the production/industrial system are effective in shaping and shifting consumption regimes, especially in premature markets such as Taiwan's.

"It's hard to expect Taiwan's consumer awareness for environmental sustainability will develop as much as those of western countries, such as Europeans, in a short time. We believe managing from the product availability could make more impact and consider consumer change in our planning road map" (C.S. at the public institute 2).

4.5. Accumulate social capability through industrialized manufacturing sectors

As of 2019, Taiwan's economy is comprised of approximately 1.5 million SMEs which cover complete industrial chains in diverse sectors. With the manufacturing expertise over the years, these players can turn to diverse and intensive network-based industries to mitigate the cost of dismantling products and identify downstream applications for (second-grade) residuals. For example, when Company 10 entered the recycled waste recovery and washing sector, recovered or recycled residuals such as re-ground

materials reinforced the company's core competence in composite material processing. Secure sourcing is critical to ensuring the quality of recycled materials as well as stabilizing costs; thus, Company 10 adopted an upstream vertical integration strategy through network alliances with both domestic and international players in the recycling industry.

"I am willing to tell you or anyone my strategy or the way I am doing business in public...because I don't think it can be copied or taken away from me...this is more the embedded know-how (social capability) and first mover's advantage (reputation and trust, again, social capability)...rather than patents played by the high-tech industry...it has been accumulated over 20 years." (Chairman at Company 10).

4.6. Discussions

The above results demonstrate that progress toward an industrial-level circular economy in Taiwan has been achieved not by luck, by a single institution, or by a single-policy solution. Rather, it has been achieved through a process of adaptive institutional governance which has facilitated the accumulation of relevant technological and social capabilities. Under this framework of adaptive institutional governance, both institutional and private entrepreneurs have identified windows of opportunity and underlying processes. These entrepreneurs have identified, selected, and acquired usable materials and connected and recombined them into fit resources through collective bricolage.

"Our government did not expect to revise regulations and legal acts so fast, because we were afraid that the stricter rules would harm industrial development. You may not believe it, but the stricter regulations were requested by the textile companies and many other companies...who are being pushed by their international buyers for certifications related to reducing carbon footprint..." (Dr. K.Y. at the public institute 1).

Our interviews revealed that many of Taiwan's SMEs identified opportunities for entrepreneurial initiatives and shared their insights through frequent formal and informal gatherings and activities held by industry-specific agencies such as public research institutes and private trade associations. These agencies serve as a platform for numerous and diverse Taiwanese SME executives who are eager to learn and share the latest developments and information across various industries and provide immediate responses to the rapidly changing market landscape.

"I am a foam producer and originally knew nothing about the recycling sector until I met Mr. Tsai at a dinner held by the Taiwan Furniture Manufacturers' Association. He is doing waste collection...he told me we can become upstream and downstream partners or set up a joint venture together if I can extrude and cut waste plastics..." (Dr. F. N. at Company 13)

This study has shown that collective bricolage requires the accumulation of social capabilities and that ensuring the representation of participants' interests in the market design is essential. In Taiwan, the entrepreneurial process of collective bricolage, along with a framework of adaptive institutional governance, has attracted new ventures and incumbents to join the recycling sector. Furthermore, profitable business models have been formulated through discussions facilitated by frequent networking activities. Reflecting the success of this process, Taiwan recycles up to 4 million tons of garbage per year; its industrial waste recycling rate has climbed to 80%; and the number of registered companies in the recycling industry increased from 107 in 2000 to 4,074 in 2017 (EPA, 2018).

The effects of the COVID-19 pandemic, which emerged at the beginning of 2020, strongly support our argument. With the rising need for face masks, respirators, ventilators, and medicines, the pandemic has reminded many countries of the value of a

domestic manufacturing base. Nations are reevaluating their reliance on global value chains based in Asian countries such as Taiwan and China, and many manufacturers have suspended production of their regular products to focus on pandemic-related products. In Taiwan, iPhone producer Foxconn and many textile companies have shifted their operations to produce face masks. Developing countries, which are most vulnerable to the pandemic, have a strong incentive to build manufacturing capacity to meet the demand for the health products needed to combat the virus. Considering the present challenges, multilateral institutions like the World Bank, the African Development Bank, and the Asian Development Bank should supply funds to support endogenous manufacturing-related projects as well as projects to build the infrastructure required for industrial development (Mathews, 2020). The pandemic is causing widespread unemployment; such a downturn is therefore an opportunity for developing countries to strategize around adaptive institutional governance so that they may industrialize endogenous manufacturing sectors in preparation for utilizing a network-based collective bricolage and transiting into green-related sectors.

5. Conclusions

The need to mitigate climate change has gained widespread recognition in many societies, but the implementation of related policies, such as raising the price of electricity to encourage the development of renewable energy, often contributes to socio-economic conflicts that delay progress. Taking Taiwan's plastic waste sector as an example, this study comes to three important conclusions. First, industrialized manufacturing sectors are foundations upon which to accumulate endogenous social capabilities and enable network-based collective bricolage. Second, network-based collective bricolages working in conjunction with adaptive institutional governance are effective strategies and are essential for developing nations that are attempting to establish circular economies based on their endogenous SMEs. Third, transitioning into green-related sectors can further drive economic development as it leads to the creation of new ventures, businesses, and job opportunities while supporting the formation of a circular economy.

Utilizing the process of industrialization to accumulate technological and social capabilities is especially critical for developing or latecomer economies where economic development is the priority. Many developing countries in Southeastern Asia, Latin America, and Africa are lacking endogenous innovation capability whereas their common strategy of institutional governance is focused on encouraging foreign investments to accelerate economic growth and industrial upgrading (Lo et al., 2020). Consequently, many leading multi-national companies (MNCs) have gained a strong foothold in these markets. With large amounts of capital, MNCs have increasingly dominated the local production system and industrial clusters. As such, the local value chains have come to be largely controlled by MNCs, making it even more difficult for SMEs to compete. Given this inherent resource disadvantage, Taiwan's experience elaborates significant implications for these countries to develop not only a self-characterized circular economy but also a well-off co-creation society. However, without accumulated technological and social capabilities over the course of industrialization, the efforts of institutional governance, entrepreneurial bricolage, and green-related transition will be ineffective toward the goal of supporting the formation of a circular economy.

This study has shed light on processes of collective bricolage which have not been well-addressed in the extant literature on entrepreneurial bricolage. We described how a network-based collective bricolage can facilitate the value transformation of waste materials and thus give rise to a new socio-economic paradigm; in this case, a circular economy. Our research indicates that the in-

dustrialized manufacturing sectors, such as the recycling sector, is the first essential milestone to induce the accumulation of technological capability as well as the social capability for achieving a circular economy. Future studies should extend and verify such approaches in other developing nations to justify the strategy moving toward a circular economy.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

The second author likes to acknowledge the funding support (108-2410-H-007 -060 -MY3) by Taiwan's Ministry of Science and Technology for this study.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:[10.1016/j.spc.2020.10.009](https://doi.org/10.1016/j.spc.2020.10.009).

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